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IEEE P2716: IEEE Guide for the characterization of the effectiveness of printed circuit board level shielding

What makes characterizing the SE of Board Levels Shields so challenging?

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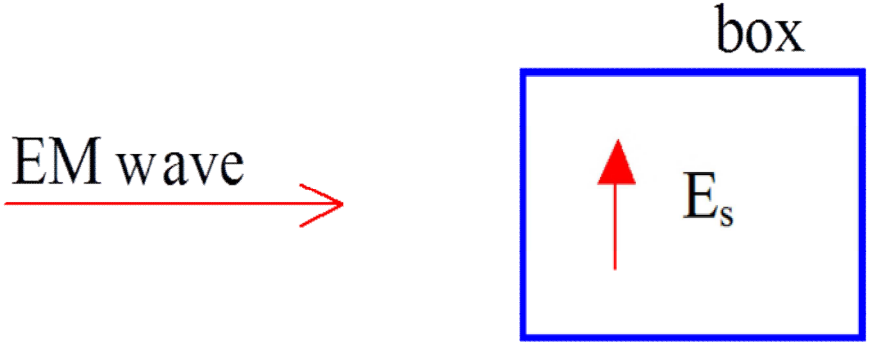
Shielded Enclosure Basics!

- A Shielded Enclosure is an electrically conducting enclosure that surrounds a piece of electronic equipment.
- Its shielding function is to prevent unwanted electromagnetic energy getting to or from the electronics inside.
- It usually has other structural and aesthetic functions.
- It can be regarded as a stand-alone structure and its Shielding Effectiveness can be assessed using standards such as IEEE 299.1.

Shielding Effectiveness: Simple view

- A simple view of Shielding effectiveness:
  - ❑As a field ratio
    - ➢ $SE = 20\log_{10}\frac{|E_0|}{|E_S|}$ dB
  - ❑As a ratio of power densities
    - ➢ $SE = 10\log_{10}\frac{S_0}{S_S}$ dB
    - ➢ $S = \frac{E_t^2}{\eta_0}$



Total field $E_t^2 = E_x^2 + E_y^2 + E_z^2$

Free space impedance

Shielding Effectiveness: Reality

- SE of an enclosure depends on:
  - Illumination
  - Measurement antenna
    - Type
    - Position
    - Polarisation
    - Orientation
  - Enclosure contents
    - Absorbs energy
    - Alters field structure

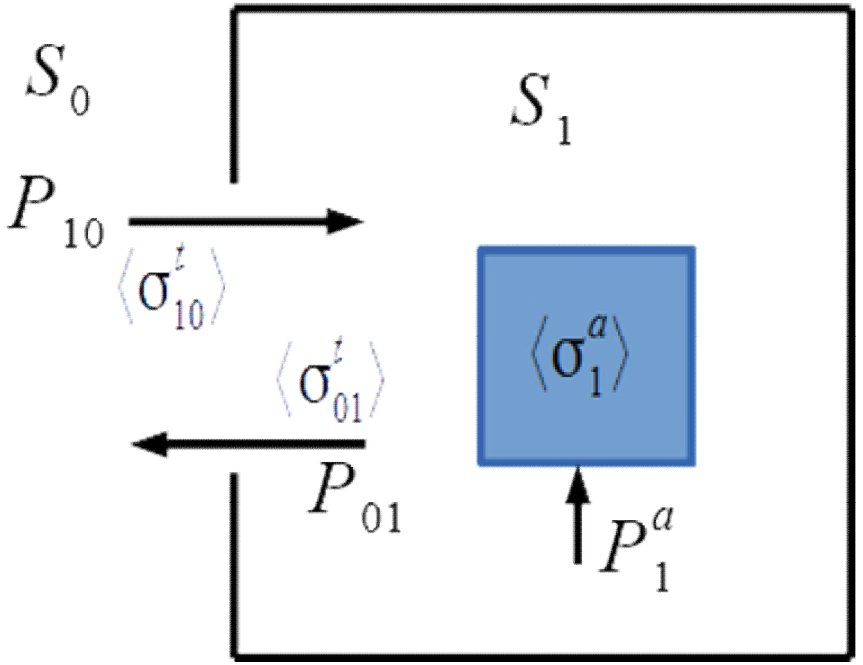
https://commons.wikimedia.org/wiki/File:Touchless_Car_Wash.jpg

https://commons.wikimedia.org/wiki/File:Air_Station_Houston_CPOA_Car_Wash_DVIDS1098879.jpg

Power Balance View : Reverberant Case

Power balance:

- $\langle P_{10} \rangle = \langle P_{01} \rangle + \langle P_1^a \rangle$
- $\langle \sigma_{10}^t \rangle S_0 = \langle \sigma_{01}^t \rangle S_1 + \langle \sigma_1^a \rangle S_1$



- So

$$SE = \frac{S_0}{S_1} = \frac{\langle \sigma_{01}^t \rangle + \langle \sigma_1^a \rangle}{\langle \sigma_{10}^t \rangle} = \frac{\langle \sigma^t \rangle + \langle \sigma_1^a \rangle}{\langle \sigma^t \rangle}$$

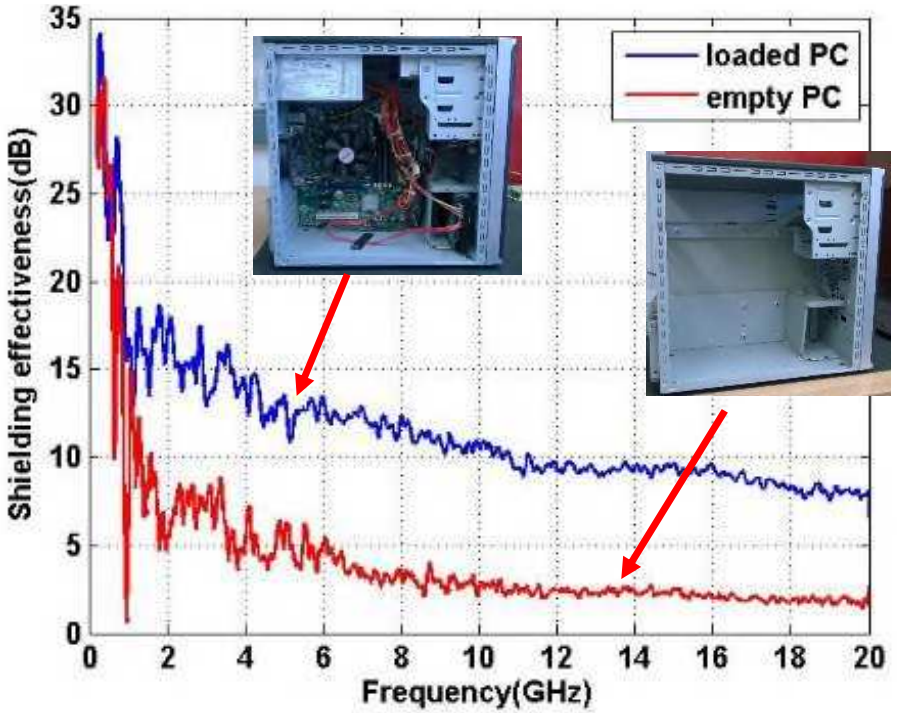
- ACS is sum of antenna, contents, and enclosure wall losses

$$\langle \sigma_1^a \rangle = \langle \sigma_{1enc}^a \rangle + \langle \sigma_{1ant}^a \rangle + \langle \sigma_{1cont}^a \rangle$$

The Meaning of Enclosure Shielding Effectiveness

- Knowing SE is not sufficient to define Enclosure shielding:
  - $SE = \frac{S_0}{S_1} = \frac{\langle\sigma^t\rangle+\langle\sigma_1^a\rangle}{\langle\sigma^t\rangle} = \langle\sigma_{1enc}^a\rangle + \langle\sigma_{1ant}^a\rangle + \langle\sigma_{1cont}^a\rangle$
- To characterise an enclosure we must know ACS and TCS of enclosure and any contents (e.g. Antenna)
- We can then predict the effect of changing the contents, if we know the ACS of each item added or removed

Effect of contents on PC Enclosure SE



What makes a Board Level Shield Different?

Typical Board Level Shield installation.

- Board Level Shields are much smaller than normal Shielded Enclosures. Typical dimensions are 100 mm or less.
- They normally have five rather than six sides. The sixth side is the circuit board ground-plane.
- Their size makes the installation of internal measurement antennas impractical in most cases meaning that standard Shielding Effectiveness measurements are not applicable.
- **Their only function is to act as a shield**.

What makes Board Level Shielding Challenging?

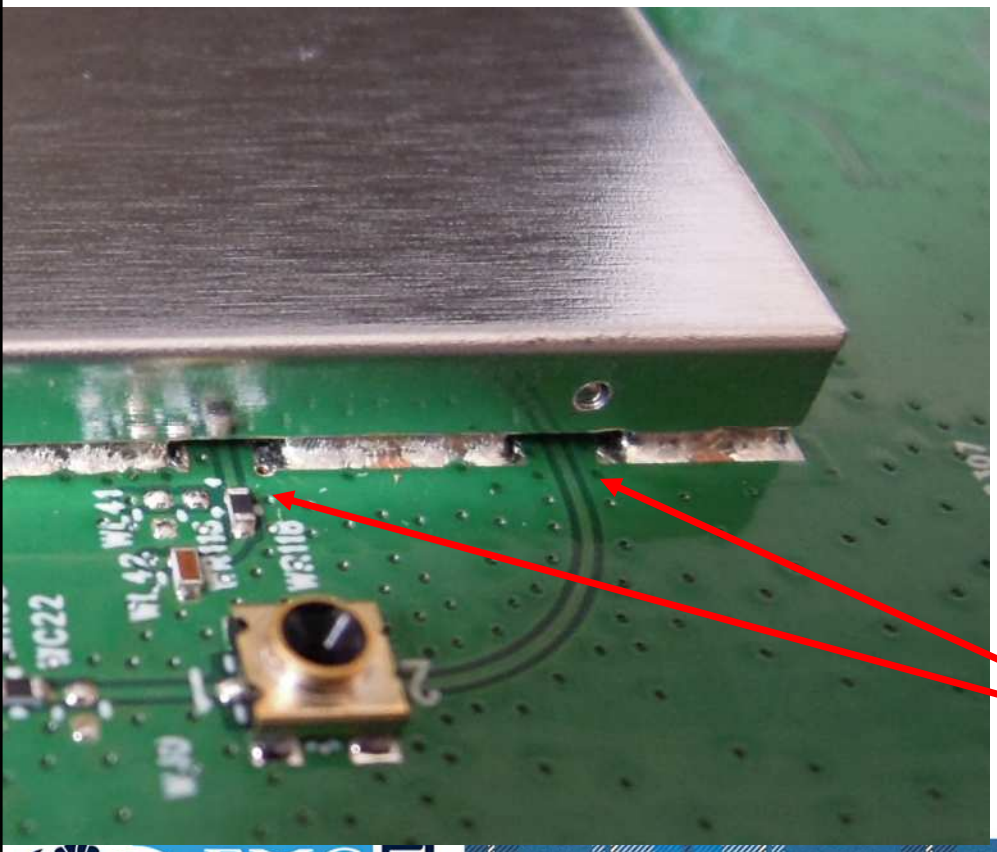
- Board Level Shields (BLS) are installed on circuit boards usually inside an outer enclosure that may itself have a shielding function.
- The function of the BLS is to isolate its internal circuits from other interference sources or sinks within the same outer enclosure, probably on the same board.
- Its external environment may be resonant, reverberant, or have multiple antennas within a few tens of mm.

Same Board Level Shield showing frame with clip-on outer shell removed.

What makes Board Level Shielding Challenging?

- BLS are non-resonant at lower frequencies < ~ 1 GHz, may be come resonant at higher frequencies > ~ 1 GHz, and may be reverberant at even higher frequencies > ~ 10 GHz. Depends on their size.
- External environment is reverberant in some measurement techniques, and not in others
  - transmission cross-section depends on illumination (σ_{10}^{t}), and internal fields (σ_{01}^{t})
- Absorption cross-section (σ_{1}^{a}) comes from the internal circuits and depends on internal field structure
- SE depends on position at which the fields are measured and antenna type (how it couples to fields).

What makes Board Level Shielding Challenging?



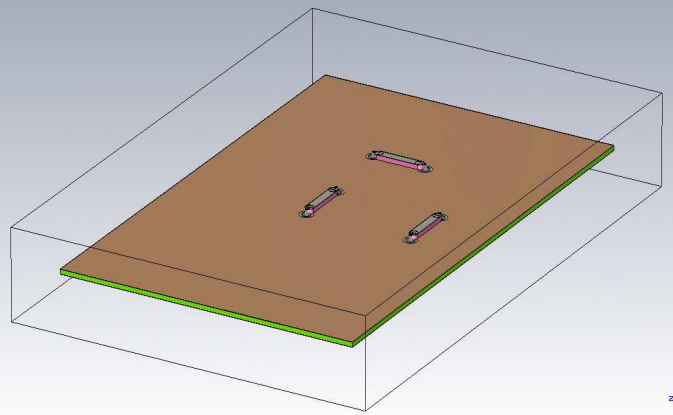
- The BLS may be installed so as to allow the propagation of desired signals between the interior and exterior of the BLS.
- Assessment of the shielding performance of BLS's must exclude these signal paths.

Measurement Techniques

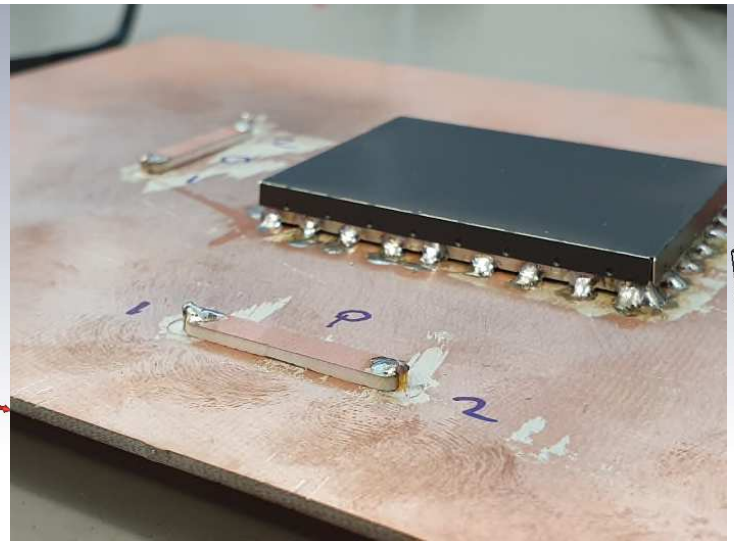
- There are several types of measurement environment applicable to Board Level Shielding Measurement; Single Reverberation Chambers, Dual Reverberation Chambers, GTEM Cells, Stripline Cells.
- They all share the same issues of variability and repeatability of installation of the Board Level Shield on the measurement system.
- The different techniques common factor is that the power measured has to pass through the Board Level Shield.
- The different ways of measuring this power in different measurement environments lead to a significant variability of different SE results.

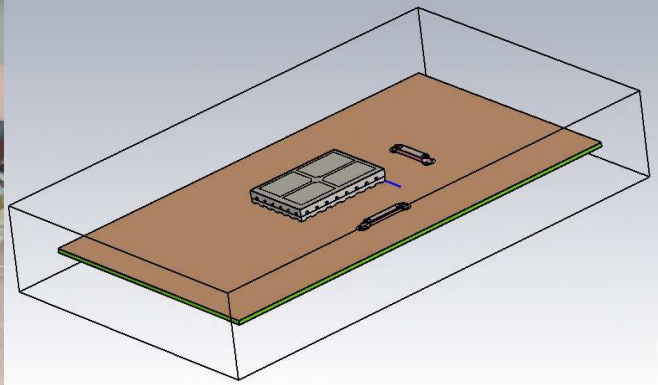
A Prototype SE Measurement Jig

The Measurement Jig shown below has strip-line circuits to mimic the internal and external stripline circuits on the circuit board allowing measurement of the coupling between them.



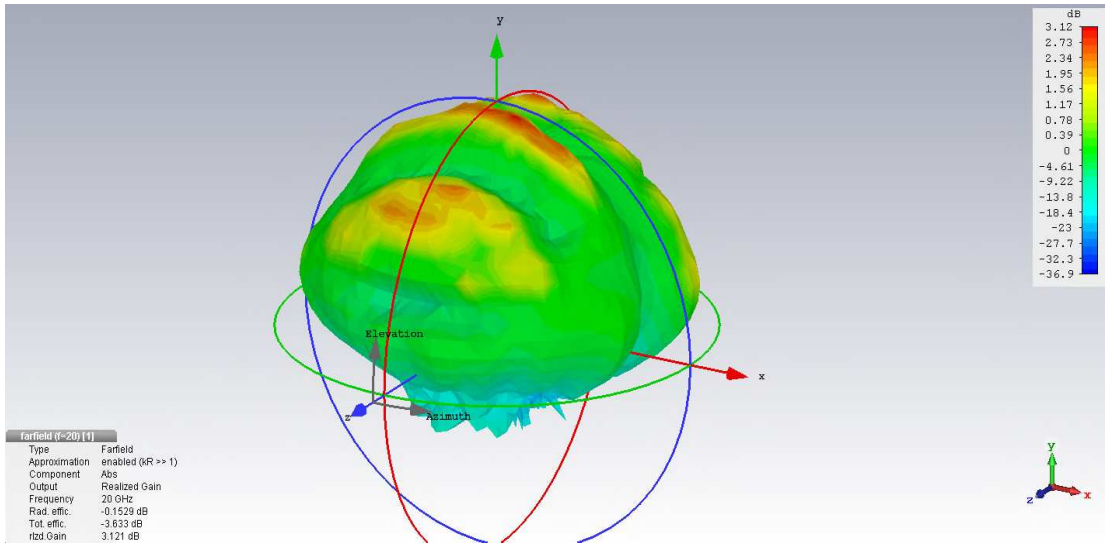
Bare jig



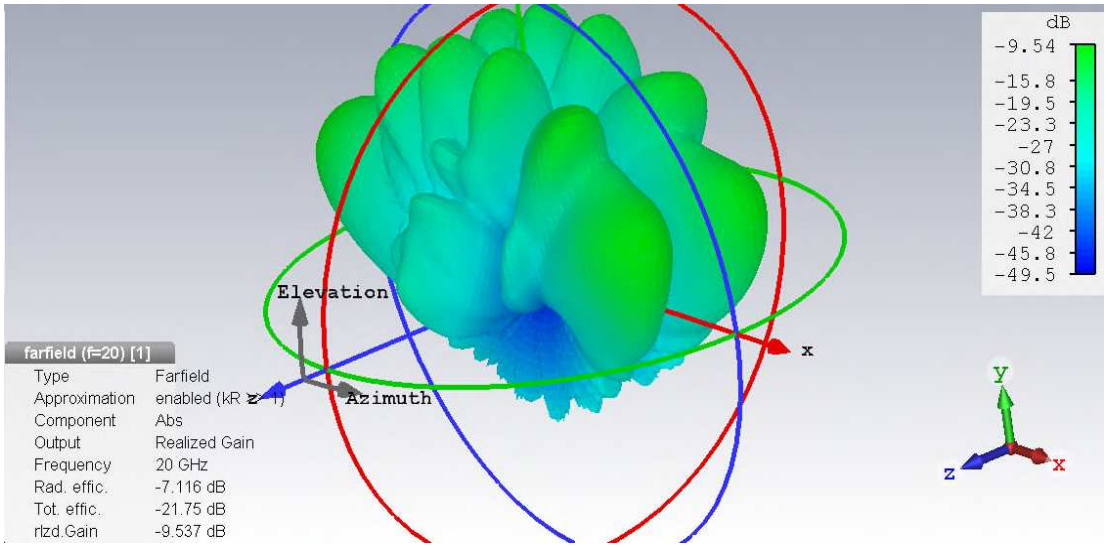


Jig with BLS

A radiation view of SE



Bare jig



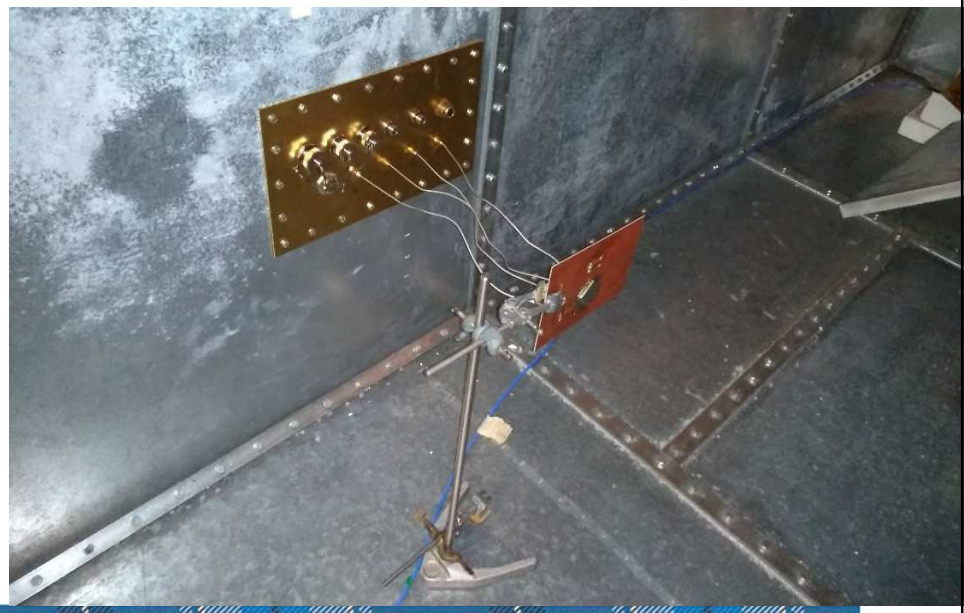
Jig with BLS

- The presence of the shield affects the radiation pattern so a fixed external antenna measurement may not give a meaningful SE measurement

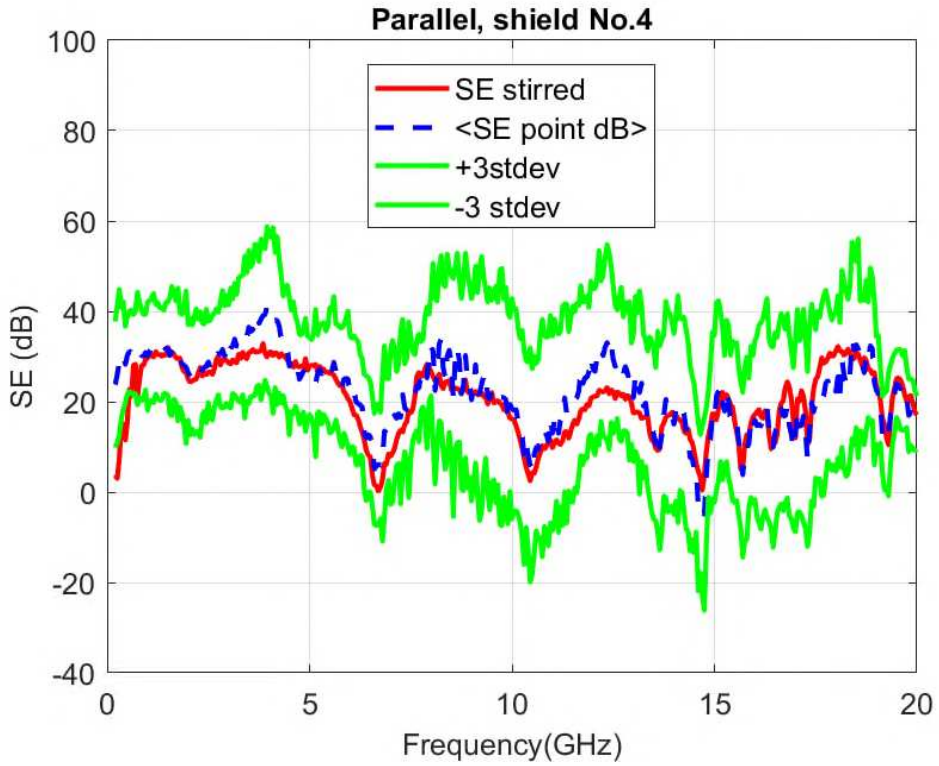
Reverberation Chamber Measurements

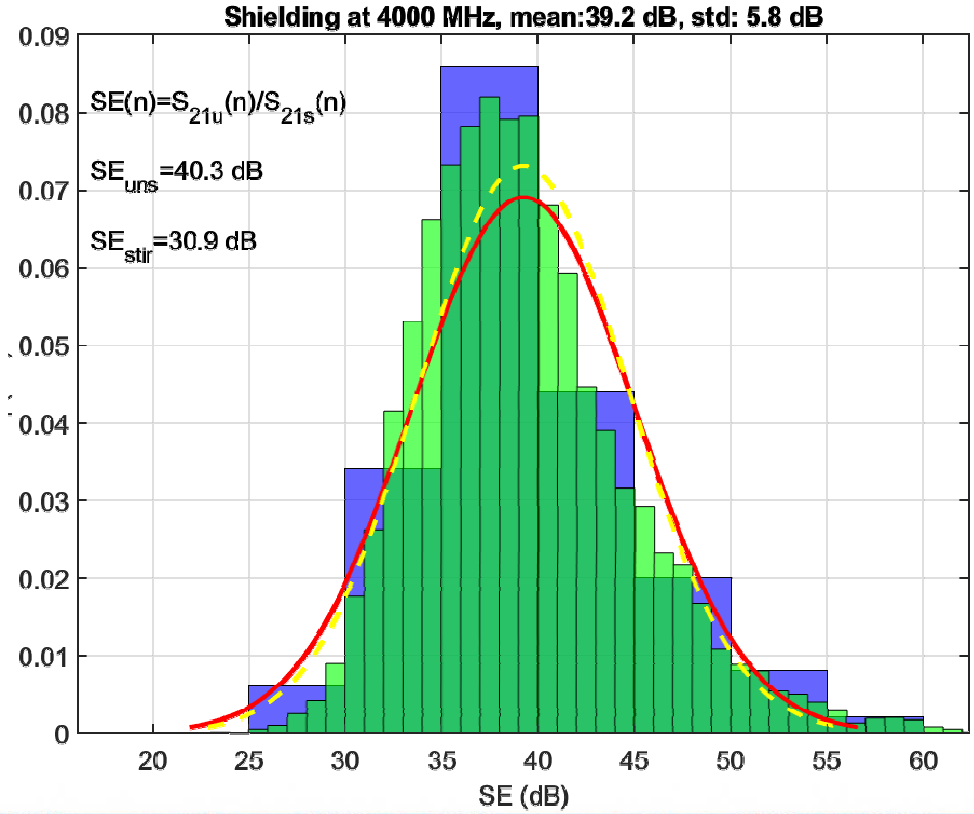
- The unknown external environment of the installed Board Level Shield can be mimicked in a reverberation chamber.
- The variability of the SE can be measured by comparing the coupling between the strip-lines on the jig at each stirrer position with and without the Board Level Shield installed.
- This is the Point SE.

Prototype SE Measurement Jig in the Reverberation Chamber.



Statistics of SE measured in a Reverberation Chamber





Conclusions

- SE can be defined and measured in many ways
  - It is not a single meaningful measure of a Board Level Shield
  - It depends on the position and orientation of the internal and external circuits that couple together (σ_{01}^{t}, σ_{10}^{t})
  - It depends on how the internal circuits absorb energy (σ_{1}^{a})
- SE is possibly a useful measure to compare similar shields
  - As long as you measure them with the same method
  - BUT different shields may have different variation of SE with variations of the external environment
  - So SE is not a simple absolute comparison. The SE variation statistics need consideration.
- SE is probably not a useful measure to predict installed performance
  - ACS and TCS may be more useful, but only maybe practical for reverberant fields